Feasibility and Status of Coal Gasification Combined Cycle Plant in JAPAN

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1.Introduction

Integrated Gasification Combined Cycle (IGCC) is regarded as the most powerful candidate for new coal firing power plant in the next generation, because of the following two points: it has a significantly high net thermal efficiency of 46-50+% which can be achieved by increasing the gas turbine inlet temperature, and it maintains superior environmental performance attained by means of a conversion process from "dirty" coal to "clean" purified gas and the disposal of glassy slag ash.

IGCC R&D in JAPAN is being carried out as a part of the "Sunshine Project", a national project concerned with promoting the use of new energies. The Ministry of International Trade and Industry(MITI) had started the IGCC R&D project in 1974 , to focus on a fluidized bed coal gasifiers. In 1986, MITI commissioned the New Energy and Industrial Technology Development Organization(NEDO) to restart an IGCC R&D project using an air blown entrained bed coal gasifier at the NAKOSO 200 ton/day pilot plant, the over all plant project schedule is shown in Figure 1.

This project, now in its final stage of the test operation, was in 1991 entrusted to the IGC Research Association by NEDO. The essential technologies for IGCC have been verified at this pilot plant through the achievement of a month of stable and continuous operation in March, 1995.

This air blown entrained bed gasification concept is more suitable for power generation as compared to the oxygen blown ones developed mainly for chemical plants in Europe and the USA, air blown ones do not require large amounts of the auxiliary power to produce oxygen (See Table 1). However, the air blown entrained bed gasification had several fault to its operation and was, therefore, never successful until our first success in April, 1995.
Due to its successful results, Mitsubishi has newly designed an IGCC system,"THE IGCC system ", which provides the highest net thermal plant efficiency and environmental benign in a cost-effective manner.

2. Results of the 200 ton/day air blown entrained bed coal gasification pilot plant operation

2.1 Outline of the 200 ton/day pilot plant

A schematic diagram of the pilot plant's system is shown in Figure 2. This plant, mainly consists of the air blown gasifier (gasifying 200 ton/day of coal), the hot and dry gas clean-up unit and the low calorie coal gas fired gas turbine (12.5MWe of capacity). The gas turbine can be tested and the performance, operational flexibility, reliability, and durability of the air blown IGCC technologies can be verified. Dry gas clean-up is composed of two parallel systems, one is a granular bed gas filter and fluidized bed desulfurization system, and the other is a candle ceramic filter and fixed bed honeycomb desulfurization system. MHI is in charge of supplying the air blown 200 ton/day gasifier, the fixed bed hot and dry gas clean-up unit and the testing stand for the full pressure and full scale gas turbine combustor.

MHI's fixed bed hot and dry gas clean-up unit is composed of a dust removal system made of a porous ceramic filter and honeycomb shaped stationary oxidized iron desulfurization unit. This system is of a significantly compact size and is completely water free. Its superior clean-up performance under high gas temperature conditions of 350~450℃ enables the effective use of sensitive heat from coal gas to be used as the gas turbine heat input. The handling system including valves, pipes and controls have been greatly simplified, as there are no moving materials, increasing system reliability and economy.
As of September 1995, the accumulative operating hours of the gasifier and the fixed bed clean-up exceeded 3800 hours and 1200 hours respectively, including the one month continuous operation of 789 hours.

It has successfully performed with the satisfactory results. The testing at the pilot plant will be completed by the end of March, 1996.

2.2 Results of the One Month Reliability Test

The 200 ton/day gasifier had achieved one month of continuous operation totaling 789 hours (about 33 days) from 3rd March to 5th April 1995. During this test period, the operation of the gasifier had been continuously stable, and the testing was completed according to the planned schedule. Table 2 shows the major operating parameters of the gasifier during this test.
It was confirmed that the gasifier can maintain sufficiently high heating values to produce coal gas for stable combustion in the gas turbine and also keep discharging continuously molten slag through the slag hole with 100% recycling of char.

Collected data shows superior performance of air blown gasification. 70% of cold gas efficiency, 99.9% of carbon conversion efficiency were obtained, and passes the highest net thermal plant efficiency at any demonstration plant. All of the ash in the coal fed to the gasifier is converted to non-leaching and compact glassy slag with negligible small unreacted carbon, thus enabling simple ash handling and economical ash disposal without fly ash, including unreacted carbon.

The fixed bed gas clean up test facility of a size of 20 ton/day had also achieved 765 hours of continuous operation during the same period of the long term reliability test operation as the 200 ton/day gasifier. This test shows 1~5 mg/Nm^3 of dust concentration and 20~50 ppm of sulfur content (H_2S,COS) at the outlet of the clean-up and the durability of the ceramic filter element, the oxidized iron desulfurization agent and the whole system.
Instead of elemental sulfur recovery system, gypsum recovery system under pressurized condition had been tested in the pilot plant.
Another advantage of this fixed bed clean-up equipment is the easiness to scale-up its capacity, because of the simple scale up criteria that requires that only the quantity of the element to be increased in accordance with the gas flow.

4. Mitsubishi IGCC system(THE IGCC system)

Based on the successful results of the 200 ton/day pilot plant, the base data for scaling-up to a 2000 ton/day class demonstration plant were able to be achieved.
The IGCC may be a more complicated system when compared to conventional fossil plants, so system integration and simplification is very important. Since MHI can supply all the key components of IGCC, MHI can drastically simplify the system based on an optimized integration among the interdependent main component and under a single responsibility.
The feasibility study on THE IGCC system has been executed, and details its superior performance and economical feasibility.

THE IGCC system is composed of the air blown two stage gasifier , the fixed bed dry gas

clean-up unit and the 1300℃ or 1500℃ class gas turbine, 701F or 701G (for 50 Hz use) and 501F or 501G (for 60 Hz use).

Adopting the fixed bed gas clean-up system, which is very compact in size and water-free, contributes to the simplicity of the whole plant system and a significant reduction of plant area. The small sized air separation unit (ASU) is installed in order to produce nitrogen as an inert gas for pressurized coal/char handling and seal gas at the gasifier. The remaining oxygen at ASU is mixed with air in the gasifier, so that the oxygen concentration in the gasifier will be 25 vol.%.
The predicted performance data is indicated in Table 3.

The net thermal efficiency of THE IGCC system is predicted to be 46~50+ LHV% It achieves a 20% reduction in the CO_2 gas emission with super critical steam condition compared with conventional pulverized coal firing power plants.
The SOx/NOx emission at the stack inlet is anticipated to be 10 ppm and the dust concentration is predicted to be less than 1 mg/Nm^3 at the inlet of the stack.
MHI is also ready to supply large capacity coal gas fired gas turbines. MHI has the proven technologies of the 1300℃ class natural gas fired gas turbines, the 1250 ℃ class blast furnace gas (BFG gas) fired gas turbines and is presently designing the 1500℃ class natural gas firing gas turbines.
MHI has also conducted coal gas firing test with the full pressure and full scale test stand of a gas turbine combustor at the 200 ton/day pilot plant. Its capacity corresponds to one can of the gas turbine for utility use. This test shows stable combustion at a low NOx conversion rate of 30~40 % (at 1000ppm of NH$_3$), which is required for the combustion of ammonia rich coal gas.
The gasifier and the gas clean-up unit can be arranged in a single steel structure. The required plant area per power output is reduced by 20% in comparison with conventional coal fired power plants.
The capital cost estimation of THE IGCC system executed at the feasibility study predicts 95% at the commercial phase when compared to conventional coal fired power plants. Consequently, THE IGCC system offers economical feasibility in the generation cost equivalent to that of the existing coal fired power plant.

5. Conclusion

The successful results of the R&D at the 200 ton/day pilot plant have verified the IGCC technologies of the air blown two stage coal gasifier and the fixed bed gas clean-up. The development of air blown IGCC has stepped up to the demonstration phase. The Mitsubishi IGCC system, composed of these technologies, is able to realize the highest net thermal efficiency and environmental benign in a cost-effective manner.

Reference :

[1] H. Ishikawa, T. Hamamatsu, H. Moritsuka, T. Toda ,S. Ishigami ,T.Furuya : *"Current Status of IGCC Development in Japan"*, VGB kraftwerkstechnik Vol. 72 No. 5 1992 p.405

[2] T. Toyoda, O. Shinada, S. Kaneko, K. Tokuda : *"Experience of 200 ton/day Coal Gasifier Operation"*, JSME/ASME International Conference on Power Generation '93 Vol. 2 1993 p. 538

[3] Takahata : *"Development of the 200 ton/day entrained coal gasification pilot plant"*, Proc. 4th The Japan Institute of Energy Congress No. 7 1995 p. 180

[4] S. Kaneko,T. Hashimoto,T. Huruya,S,Uchida,A,Hashimoto : *"Operation Experience with Air Blown 200ton/day Entrained Bed Coal Gasifier"* POWER GEN in 1996

TYPE	Gasifying Agent		Coal Feed		Gas Clean-up		Thermal Efficiency
	Air	Oxygen	Dry	Wet	Dry	Wet	
NEDO/IGC/MHI	○		○		○		High
Oxygen Blown Type A		○	○			○	Medium
Oxygen Blown Type B		○		○		○	Medium

Table 1 Comparison of IGCC System

	Unit	Plan	Result
Coal Gas Calorie (HHV)	kJ/m³N	4,150	4,200~4,600
Coal Gas Flow	T/hr	50.2(at 100%LOAD)	40(75%)~50(100%)
Sulfur Concentration (Inlet)	ppm	<1,500	570~670
Sulfur Concentration (Outlet)	ppm	<100	20~50
Dust Concentration (Inlet)	mg/ m³N	<3,000	180~230
Dust Concentration (Outlet)	mg/ m³N	<10	~1.1

Table 2 One Month Continuous Operation Data of the Pilot Plant

	Unit	Demonstration Plant		Commercial Plant	
Target	year	2000		2010	
Cycle	Hz	50	60	50	60
Gasifier	-	Air Blown Two Stage Entrained Bed Type			
Capacity	t/day	2,400	1,700	3,100	2,300
Dust Removal	-	Porous Ceramic Filter Type			
Desulfurization	-	Honeycomb Fixed Bed Type			
Gas Turbine	-	701F	501F	701G	501G
Gross Output	MW	400	275	546	408
Net Output	MW	368	255	510	380
Gross Efficiency	% LHV	46	46	50	50
SOx/NOx Emission	ppm	10/10			
Dust Emission	mg/m³N	1			

Table 3 Major Specification of THE IGCC system

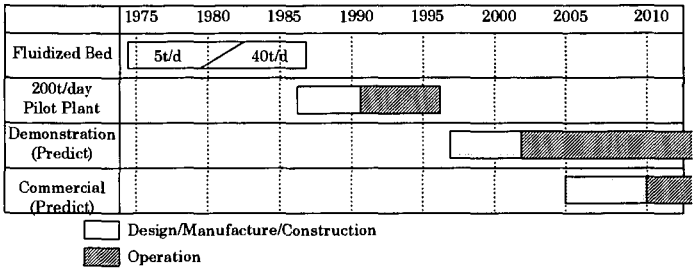

Figure 1 Master Schedule of IGCC Project in JAPAN

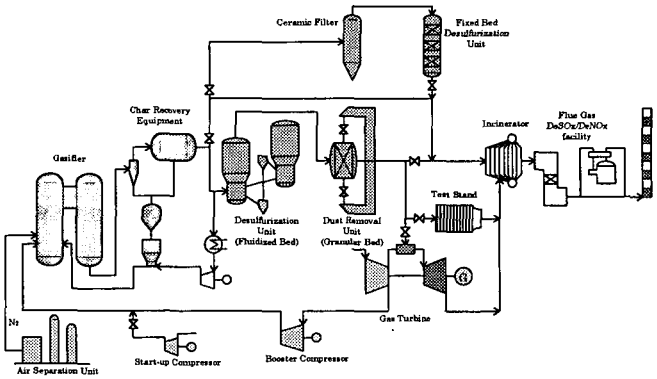

Figure 2 System Flow Diagram of 200ton/day pilot plant

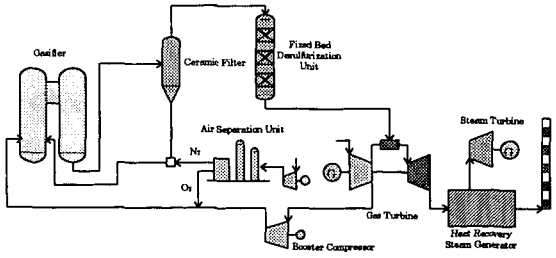

Figure 3 System Flow Diagram of THE IGCC plant